

## NREL RESEARCH

# Hybrid Electric Vehicle Research

*Developing tomorrow's vehicles today*

Vehicles powered by internal combustion engines produce tailpipe emissions that cause much of today's environmental pollution. Electric vehicles do not generate tailpipe emissions, but currently cost more and lack the range of conventional vehicles. Hybrid electric vehicles (HEVs) combine the best of both—the performance and driving range of conventional vehicles and the fuel efficiency and low emissions of electric vehicles. That's why the goal of a joint research effort between the U.S. Department of Energy (DOE) and the U.S. automotive industry is to make HEVs common on our roads by the year 2003.

## What Are HEVs?

Unlike conventional vehicles, HEVs are propelled by two energy sources—an auxiliary power unit (such as a combustion engine or fuel cell) and an electric propulsion system (which includes an energy storage device such as batteries, ultracapacitors or flywheels). The combined propulsion system will make HEVs two to three times more efficient than conventional vehicles and still provide similar comfort and performance. HEVs have either a parallel or series design.

**Parallel Design**—With this configuration, the primary engine and electric propulsion system are connected directly to the vehicle's wheels. The primary engine is used for highway driving, while the electric motor provides added power during hill climbs, acceleration and other periods of high energy demand.

**Series Arrangement**—In a series design, the primary engine is connected to a generator that produces electricity. The electricity is either stored in batteries or sent to an electric motor that powers the wheels.

## HEV Propulsion Program

NREL provides technical management of the U.S. Department of Energy's (DOE) HEV Propulsion Program, a multimillion dollar program in which research costs are shared by the government and the automotive industry. Part of DOE's Partnership for a New Generation of Vehicles program, the HEV program includes General Motors (GM), Ford, Chrysler and their suppliers.



The goal of the HEV program is to develop and demonstrate production feasible HEV propulsion systems by 1998, first generation systems by 2000 and market-ready HEVs by 2003.

Program partners are working to develop HEVs that have twice the fuel efficiency of conventional vehicles; meet the most stringent emission standards; and are similar in performance, range, safety and cost to conventional vehicles.

## NREL's Role

NREL provides the auto makers an external perspective on advanced automobile development, offering systems level technical expertise and original solutions from an energy conservation and fuel efficiency perspective. Four examples of NREL's collaboration with the automotive industry follow.

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**ADVISOR**—When developing an advanced vehicle to achieve ultra-low emissions and triple the fuel economy, all energy flows must be carefully managed. To answer this need, NREL developed the ADVISOR computer software simulation program. ADVISOR estimates and evaluates HEV and component performance. The physics-based model estimates vehicle performance based on various parameters (such as vehicle mass, engine size and tire size) and is used to calculate and predict fuel saving opportunities. In conjunction with Chrysler, Ford, and GM, the model is validated with experimental data.

**Rapid Structural and Fluid Dynamics**—Vehicle research and development time can be dramatically reduced by using computer-aided engineering tools. NREL's unique expertise combines computer engineering software programs to create a portfolio of tools for assessing the structural stability of components, analyzing component performance and evaluating flow performance. NREL has provided industry with rapid design change recommendations for improving advanced vehicle components.

**Thermal Energy Management**—Without proper thermal management, energy storage devices (such as batteries) may never achieve their optimal performance and may have shorter life cycles. NREL's thermal energy management research focuses on optimizing the performance and durability of the power unit and energy storage devices by maintaining and managing appropriate temperatures and control loops. The goal is to keep them from becoming too hot or too cold, either of which can hamper performance.

**Auxiliary Loads**—The work put into propulsion system development is not enough to make a vehicle efficient enough to meet the program's efficiency goals. NREL's research seeks to reduce the energy needed to cool and heat vehicles. The energy saved can instead be used to power the vehicle. Photovoltaics, electrochromic windows and load leveling techniques for peak load reduction are just a few of the approaches being considered.

## **Benefits**

**Increased Efficiency**—Engines in HEVs never idle and are sized to average load, not peak load. This reduces their weight. Electronic controllers keep vehicles operating at their most efficient level. Efficiency is further increased through regenerative braking which captures and stores energy that is otherwise lost during braking.

**Reduced Vehicle Emissions**—By operating on alternative fuels such as ethanol, methanol, natural gas, propane and electricity, HEVs will produce far fewer harmful emissions than conventional vehicles.

**Economics**—Since HEVs are efficient, and can operate on alternative fuels, they will help decrease the nation's dependence on foreign oil and help reduce the nation's trade deficit, improve energy security and create domestic jobs.

## **Challenges**

Major challenges that must be resolved before HEVs can effectively penetrate the market include: establishing consumer acceptance and developing a propulsion system that offers similar performance and safety as vehicles powered by internal combustion engines.

More information is available from the HEV web site at <http://www.hev.doe.gov>.